[Name of Document] SPECIFICATION

[Title of the Invention] VIBRATOR

[Claims]

[Claim 1] A vibrator characterized by comprising:

a vibrating body;

driving means for causing said vibrating body to vibrate in a predetermined vibrating direction; and

driving monitoring means for detecting vibration displacement, in a driving direction of said vibrating body, in said vibrator in which stabilization of vibration in the driving direction of said vibrating body is achieved by applying positive feedback control to said driving means based on the state of the vibration displacement in the driving direction of said vibrating body detected by this driving monitoring means,

wherein said driving monitoring means has a construction so as to be provided in a barycentric region of said vibrating body and to detect the vibration displacement in the driving direction of the barycentric region of said vibrating body.

[Claim 2] A vibrator according to Claim 1, characterized in that said vibrating body has a construction in which flexible vibration can be obtained in the driving direction thereof and in a Coriolis force direction that is substantially perpendicular to said driving direction,

Coriolis force direction vibrating detecting means for detecting the vibration displacement in the Coriolis force direction of said vibrating body is provided, and the angular velocity of rotation around a central axis having a direction perpendicular to both said driving direction and said Coriolis force direction is found based on the vibration in the Coriolis force direction of said vibrating body detected by said Coriolis force direction vibrating detecting means.

[Claim 3] A vibrator according to Claim 1 or Claim 2, characterized in that said vibrating body has a double-frame construction obtained by connecting an inner frame to the inside of an outer frame via a coupling beam so that said vibrating body can flexibly vibrate in the Coriolis force direction, said driving means causes said outer frame and said inner frame to vibrate in an integral manner in the driving direction, said inner frame has a construction so as to be vibrated in the Coriolis force direction with respect to said outer frame due to the Coriolis force caused by the angular velocity, and said driving monitoring means is provided in the barycentric region of said vibrating body disposed inside said inner frame while being supported by said inner frame.

[Detailed Description of the Invention]

[0001]

[Technical Field of the Invention]

The present invention relates to a vibrator constituting an angular velocity sensor or the like.

[0002]

[Description of the Related Art]

Fig. 4 illustrates a construction example of a vibrator constituting an angular velocity sensor using a top view. A vibrator 2 of an angular velocity sensor 1 shown in this Fig. 4 includes a substrate 3 in which a support fixed unit 4, comb-shaped driving fixed electrode units 5 (5a, 5b, 5c, 5d, 5e, 5f, 5g, 5h) and detecting fixed electrode units 6 (6a, 6b, 6c, 6d, 6e, 6f) are each disposed in a fixed manner on the top face thereof. A vibrating body 8 is connected to the support fixed unit 4 via support units 7 (7a, 7b).

[0003]

The vibrating body 8 which is disposed maintaining a distance from the substrate 3, which can vibrate, and which is constructed by including driving beams 9 (9a, 9b, 9c, 9d), an outer frame 10, comb-shaped driving movable electrode units 11 (11a, 11b, 11c, 11d, 11e, 11f, 11g, 11h), support units 12 (12a, 12b), detecting beams 13 (13a, 13b, 13c, 13d) that are coupling beams, an inner frame 14, and comb-shaped detecting moveable electrode units 15 (15a, 15b, 15c, 15d, 15e, 15f).

[0004]

That is, one end side of each of the above driving beams 9a and 9b is commonly connected to the above support unit 7a, one end side of each of the driving beams 9c and 9d is commonly connected to the above support beam 7b, and the other end side of each of the above driving beams 9a, 9b, 9c, and 9d is commonly connected to the outer frame 10.

[0005]

This outer frame 10, as described later, can vibrate in an X direction shown in Fig. 4. The comb-shaped driving moveable electrode units 11 are each provided in the outer frame 10 so as to be engaged with the corresponding comb-shaped driving fixed electrode units 11 maintaining a distance therebetween. Pairs of the above driving fixed electrode units 5a, 5b, 5c, and 5d and the driving moveable electrode units 11a, 11b, 11c, and 11d that correspondingly face each other constitute a first driving unit (driving means), and pairs of the above driving fixed electrode units 5e, 5f, 5g, and 5h and the driving moveable units 11e, 11f, 11g, and 11h constitute a second driving unit (driving means).

[0006]

The support units 12a and 12b are each formed in the above outer frame 10 so as to extend towards inside of the outer frame 10. Furthermore, the detecting beams 13a and 13b are each formed so as to extend from the end side of the

above support unit 12a while the detecting beams 13c and 13d are each formed so as to extend from the support beam 12b.

[0007]

The inner frame 14 is commonly connected to the extended edge side of each of the above detecting beams 13a, 13b, 13c, and 13d. This inner frame 14 can vibrate integrally with the above outer frame 10 in the X direction, as described below, and can vibrate in a Y direction with respect to the above outer frame 10. The comb-shaped detecting moveable electrode units 15 are each provided in the inner frame 14 so as to be engaged with the above corresponding comb-shaped detecting fixed electrode units 6 maintaining a distance therebetween. Pairs of the above detecting fixed electrode units 6a, 6b, and 6c and the detecting moveable electrode units 15a, 15b, and 15c that correspondingly face each other constitute a first detecting unit (vibration detecting means in the Coriolis force direction). Pairs of the detecting fixed electrodes 6d, 6e, and 6f and the detecting moveable electrode units 15d, 15e, and 15f constitute a second detecting means (vibration detecting means in the Coriolis force direction). Among a plurality of pairs of the detecting fixed electrode units 6 and the detecting moveable electrode units 15 that constitute the above first and second detecting units, the pair of the above detecting fixed electrode unit 6c and the

detecting moveable electrode unit 15c and the pair of the detecting fixed electrode unit 6f and the detecting moveable electrode unit 15f constitute driving monitoring means.

[0008]

A conductor pattern for supplying electric power from the outside to each of the above driving fixed electrode units 5 and a conductive pattern for conductively connecting to each of the detecting fixed electrode units 6 are formed though they are not shown.

[0009]

The vibrator 2 shown in Fig. 4 is constructed in the above-described manner. In this vibrator 2, when an alternating driving voltage (driving signal) is applied between the above driving fixed electrode units 5 and the driving moveable electrode units 11 that face each other, making use of elasticity of each of the above driving beams 9, the overall vibrator 8 driving-vibrates in the X direction shown in Fig. 4, in which the support units 7a and 7b are caused to serve as fulcrums, in accordance with change in the magnitude of electrostatic force based on the driving voltage.

[0010]

In a state in which the overall vibrating body 8 is driven in the X direction in this manner, when the vibrating body 8 rotates on a Z direction (in the direction

perpendicular to the drawing), the Coriolis force is generated in a direction, which is perpendicular to both the driving direction (X direction) of the above vibrating body 8 and the center axis direction (Z direction) of rotation of the above vibrating body 8, that is, in the Y direction. This Y-direction Coriolis force causes the inner frame 14 of the above vibrating body 8 to detecting-vibrate, in which the support units 12a and 12b are caused to serve as the fulcrums, in the Y direction relatively to the above outer frame 10, making use of elasticity of each of the above detecting beams 13.

[0011]

By detecting the change in the capacitance between the above detecting fixed electrode units 6 and detecting moveable electrode units 15 based on this Y-direction detecting-vibration, the magnitude of the angular velocity around the Z axis can be detected.

[0012]

Normally, in order to avoid adverse effects such as air damping, the above vibrator 2 is contained in a housing space defined by, for example, a glass member and is sealed in a depressurized state. In this case, the above driving fixed electrode units 5 and the detecting fixed electrode units 6 of the vibrator 2 are constructed so as to be conductively connectable to the outside via a through-hole

disposed in, for example, the above glass member.

[0013]

In Fig. 5, one example of a signal processing circuit connected to the above vibrator 2 is shown along with main parts of the above vibrator 2. This signal processing circuit 20 is constructed by including a first detecting C-V converting unit 21, a second C-V converting unit 22, a summing amplifying unit 23, a differential amplifying unit 24, an AGC (Auto Gain Control) unit 25, a phase inverting unit 26, and a synchronous detecting unit 27. In Fig. 5, the driving fixed electrode units 5, the detecting fixed electrode units 6, and the vibrating body 8 of the above vibrator 2 are illustrated in a simplified manner so that the construction of the signal processing circuit can be easily described.

[0014]

The above first detecting C-V converting unit 21 has a construction for converting the total capacitance between the detecting fixed electrode units 6 (6a, 6b, 6c) and the detecting moveable electrode units 15 (15a, 15b, 15c), which constitute the first detecting unit of the above vibrator 2, into a voltage and for outputting the converted signal. The above second detecting C-V converting unit 22 has a construction for converting the total capacitance between the detecting fixed electrode units 6 (6d, 6e, 6f) and the

detecting moveable electrode units 15 (15d, 15e, 15f), which constitute the above second detecting unit, into a voltage and for outputting the converted signal.

[0015]

When the above vibrating body 8 driving-vibrates only in the X direction, the signal output from the above first detecting C-V converting unit 21 is a signal A1 having a waveform indicated by, for example, a dashed line A1 in Fig. 6(a). The signal output from the above second detecting C-V converting unit 22 is a signal A2 having a waveform indicated by a dashed line A2 in Fig. 6(b). The signal A2 has the same amplitude and phase as those of the signal A1 output from the above first detecting C-V converting unit 21. The phases of the signals A1 and A2 caused by these driving-vibrations are displaced from the phase of a driving signal applied between the driving fixed electrode units 5 and the driving moveable electrode units 11 for causing the vibrating body 8 to driving-vibrate by 90°.

[0016]

In the example shown in Fig. 4, the detecting fixed electrode unit 6a and the detecting fixed electrode unit 6b, the detecting moveable electrode unit 15a and the detecting moveable electrode unit 15b, the detecting fixed electrode unit 6d and the detecting fixed electrode unit 6e, and the detecting moveable electrode unit 15d and the detecting

moveable electrode unit 15e have the symmetric relationship, respectively. Hence, due to the driving vibration in the above X direction, the change in the capacitance between the above detecting fixed electrode unit 6a and the detecting moveable electrode unit 15a and the change in the capacitance between the above detecting fixed electrode unit 6b and the detecting moveable electrode unit 15b are counterbalanced. Likewise, due to the vibration in the above X direction, the change in the capacitance between the above detecting fixed electrode unit 6d and the detecting moveable electrode unit 15d and the change in the capacitance between the above detecting fixed electrode unit 6e and the detecting moveable electrode unit 15e are counterbalanced.

[0017]

Because of this, when the vibrating body 8 driving-vibrates only in the X direction, the signal A1 output from the above first detecting C-V converting unit 21 responds to the change in the capacitance only between the above detecting fixed electrode unit 6c and the detecting moveable electrode unit 15c. The signal A2 output from the above second detecting C-V converting unit 22 responds to the change in the capacitance only between the above detecting fixed electrode unit 6f and the detecting moveable electrode unit 15f. In other words, the vibration in the X direction

of the vibrating body 8 (driving direction) can be detected by the above detecting fixed electrode units 6c and 6f and the detecting moveable electrode units 15c and 15f that are driving monitoring means.

[0018]

When the inner frame 14 of the vibrating body 8 vibrates not only in the above X direction but also in the Y direction (Coriolis force direction) due to the angular velocity around the Z-axis shown in Fig. 4, the output signal from the first detecting C-V converting unit 21 is a signal obtained by overlapping the signal component A1 due to the above driving vibration and a signal component B1 due to the angular velocity having the waveform indicated by a solid line B1. The above signal component B1 has the magnitude of the amplitude in accordance with the magnitude of the angular velocity. The above signal components A1 and B1 are 90° out of phase.

[0019]

When the angular velocity is generated, the output signal from the second detecting C-V converting unit 22 is a signal obtained by overlapping the signal component A2 caused by the above driving vibration and a signal component B2 caused by the angular velocity having the waveform indicated by a solid line B2 in Fig. 6(b). The above signal component B2 has the magnitude of the amplitude in

accordance with the magnitude of the angular velocity. In other words, the signal component B2 has substantially the same magnitude of the amplitude as that of the signal component B1 of the output signal from the above first detecting C-V converting unit 21. The phase of the signal component B2 is displaced by 90° from that of the above signal component A2 and is displaced by 180° from that of the signal component B1 of the output signal from the above first detecting C-V converting unit 21.

[0020]

In addition, there is a case in which the above inner frame 14 vibrates caused by not only the angular velocity but also the acceleration in the Y direction. In this case, the output signal from the above first detecting C-V converting unit 21 becomes a signal obtained by overlapping the signal component A1 based on the above driving vibration, the signal component B1 caused by the above angular velocity, and a signal component C1 having the waveform indicated by a dashed line C1 in Fig. 6(a) due to the acceleration. The above signal component C1 has the magnitude of the amplitude in accordance with the magnitude of the acceleration and has the same phase as that of the above signal component A1.

[0021]

When the angular velocity and the acceleration are generated, the output signal from the above second detecting

C-V converting unit 22 becomes a signal obtained by overlapping the signal component A2 based on the above driving vibration, the signal component B2 caused by the above angular velocity, and a signal component C2 having the waveform indicated by a dashed line C2 in Fig. 4(b) due to the acceleration. The above signal component C2 has the magnitude of the amplitude in accordance with the magnitude of the acceleration. In other words, the signal component C2 has the amplitude having substantially the same magnitude as that of the amplitude of the signal component C1 of the output signal from the above first detecting C-V converting unit 21. The phase of the signal component C2 is displaced from those of the above signal component A2 and the signal component C1 by 180°.

[0022]

In the above-described manner, the first detecting C-V converting unit 21 and the second detecting C-V converting unit 22 each output a signal in accordance with the vibration state of the vibrating body 8 to the summing amplifying unit 23 and the differential amplifying unit 24.

[0023]

The summing amplifying unit 23 applies summing-amplifying to the output signal from the above first detecting C-V converting unit 21 and the output signal from the second detecting C-V converting unit 22. Addition of

the signal by this summing amplifying unit 23 causes the signal component B1 of the output signal from the first detecting C-V converting unit 21 caused by the above angular velocity and the signal component B2 of the output signal from the second detecting C-V converting unit 22 to be counterbalanced and be removed. Likewise, the signal component C1 and the signal component C2 caused by the acceleration are counterbalanced and removed. Because of this, the summing amplifying unit 23 outputs a signal in response to only a signal component, due to the driving vibration, obtained by adding the above signal component A1 and signal component A2 as a driving detecting signal (monitoring signal) to the AGC unit 25 and the synchronous detecting unit 27.

[0024]

The AGC unit 25 outputs the driving signal by means of the positive feedback control so that the above vibrating body 8 stably vibrates in the driving direction at the resonant frequency based on the above driving detecting signal. Among the pair of the driving fixed electrode units 5 (5a, 5b, 5c, 5d) and the driving moveable electrode units 11 (11a, 11b, 11c, 11d) that constitute the first driving unit and the driving fixed electrode units 5 (5e, 5f, 5g, 5h) and the driving moveable electrode units 11 (11e, 11f, 11g, 11h) that constitute the second driving unit, the

driving signal is applied directly into one of the driving units (the above first driving unit in the example shown in Fig. 5) while the a driving signal obtained by causing the phase inverting unit 26 to phase-invert the above driving signal is applied to the other of the driving units. Application of this driving signal drives the vibrating body 8 into vibrating in the above-described manner. That is, in the vibrating body 8 positive feedback control is applied to each of the first and second driving units based on the vibrating state of the vibrating body 8 in the vibrating direction (X direction) detected by the driving monitor means, so that the vibration stabilization of the vibrating body 8 in the driving direction thereof is achieved.

[0025]

The differential amplifying unit 24 obtains the difference between the signal output from the above first detecting C-V converting unit 21 and the signal output from the second detecting C-V converting unit 22. The differential of the signals of this differential amplifying unit 24 causes the signal component A1 due to the driving vibration in the output signal from the above first detecting C-V converting unit 21 and the signal component A2 due to the driving vibration in the output signal from the second detecting C-V converting unit 22 to be counterbalanced. Because of this, the differential

amplifying unit 24 outputs the angular velocity/acceleration mixed signal to the synchronous detecting unit 27 based on a signal component B3, indicated by a solid line B3 in Fig. 7, obtained by adding the above signal component B1 and the signal component B2 due to the angular velocity and a signal component C3, indicated by a dashed line C3 in Fig. 7, obtained by adding the signal component C1 and the signal component C2 due to the acceleration.

[0026]

The synchronous detecting unit 27 is integrated with a phase shifter (not shown), which causes the phase of the driving detecting signal output from the above summing amplifying unit 23 to be displaced by 90° to generate an angular velocity reference signal. The angular velocity/acceleration mixed signal output from the above differential amplifying unit 24 is synchronously detected making use of this angular velocity reference signal.

[0027]

That is, the angular velocity reference signal is a signal whose phase is equal to or is displaced by 180° from that of the angular velocity component B3 of the above angular velocity/acceleration mixed signal. The synchronous detecting unit 27 integrates (synchronously detects) the angular velocity/acceleration mixed signal in a region D1 of the phase of the angular velocity reference signal of 0° to

180° and in a region D2 of the phase of the angular velocity reference signal of 180° to 360°. Since this synchronous detection removes the acceleration component C3 of the above angular velocity/acceleration mixed signal, the synchronous detecting unit 27 outputs a signal in accordance with the angular velocity component B3 as the angular velocity signal. The magnitude of the angular velocity can be detected using this angular velocity signal.

[0028]

[Problems to be Solved by the Invention]

In order that an outer frame 10 and an inner frame 14 of the above vibrating body 8 ideally vibrate, a driving beams 9, the outer frame 10, detecting beams 13, an inner frame 14, and the like that constitute the above vibrating body 8 are preferably symmetric with respect to dashed lines A and B shown in Fig. 4. However, since, from the point of view of machining accuracy, it is substantially impossible to make the above driving beam 9, the outer frame 10, detecting beams 13, and the inner frame 14 in the above-described precisely symmetric manner, the above driving beams 9, the outer frame 10, the detecting beams 13, and the inner frame 14 become asymmetric.

[0029]

When the acceleration in a Y direction is applied to the vibrating body 8, this asymmetry sometimes causes the

vibrating body 8 to rotating-vibrate around, for example, an X-direction axis. When unwanted rotating-vibration is generated due to such acceleration, the capacitances between the detecting fixed electrode units 6c and 6f and the detecting moveable electrode units 15c and 15f that are driving monitoring means are changed due to not only driving-vibration of the vibrating body 8 caused by each of first and second driving units but also the influence of the unwanted rotating vibration caused by the above acceleration. This leads to a state in which driving vibration signal components A1 and A2 of a signal output from the first C-V converting unit 21 and a second C-V converting unit 22 pick up noises caused by the acceleration.

[0030]

Therefore, since the vibrating state of the vibrating body 8 in the driving direction cannot be accurately obtained, the disturbance occurs in the positive feedback control of the driving vibration of the vibrating body 8, which arises a problem in that driving vibration of the vibrating body 8 becomes unstable. Thus, when the driving vibration of the vibrating body 8 becomes unstable, for example, a synchronous detecting unit 27 does not correctly generate a synchronous detecting reference signal, which leads to a problem in that the accurate angular velocity signal cannot be output.

[0031]

The present invention is made for solving the foregoing problems, and the object thereof is to provide a vibrator for capable of preventing disturbance in the vibration of the vibrating body in the driving direction caused by the unwanted rotating vibration.

[0032]

[Means for Solving the Problems]

To achieve the foregoing goal, this invention uses the following construction as means for solving the foregoing problems. That is, a vibrator in a first aspect of the invention has a construction obtained by including: a vibrating body; driving means for causing the vibrating body to vibrate in a predetermined vibrating direction; and driving monitoring means for detecting vibration displacement, in a driving direction of the vibrating body, in the vibrator in which stabilization of vibration in the driving direction of the vibrating body is achieved by applying positive feedback control to the driving means based on the state of the vibration displacement in the driving direction of the vibrating body detected by this driving monitoring means, wherein the driving monitoring means has a construction so as to be provided in a barycentric region of the vibrating body and to detect the vibration displacement in the driving direction of the

barycentric region of the vibrating body. This construction serves as means for solving the problems.

[0033]

A vibrator in a second aspect of the invention is provided with the construction of the first aspect of the invention and has the construction that is characterized in that the vibrating body has a construction in which flexible vibration can be obtained in the driving direction thereof and in a Coriolis force direction that is substantially perpendicular to the driving direction, Coriolis force direction vibrating detecting means for detecting the vibration displacement in the Coriolis force direction of the vibrating body is provided, and the angular velocity of rotation around a central axis having a direction perpendicular to both the driving direction and the Coriolis force direction is found based on the vibration in the Coriolis force direction of the vibrating body detected by the Coriolis force direction vibrating detecting means.

[0034]

A vibrator in a third aspect of the invention is provided with the construction of the first or second aspect of the invention and has the construction that is characterized in that the vibrating body has a double-frame construction obtained by connecting an inner frame to the inside of an outer frame via a coupling beam so that the

vibrating body can flexibly vibrate in the Coriolis force direction, the driving means causes the outer frame and the inner frame to vibrate in an integral manner in the driving direction, the inner frame has a construction so as to be vibrated in the Coriolis force direction with respect to the outer frame due to the Coriolis force caused by the angular velocity, and the driving monitoring means is provided in the barycentric region of the vibrating body disposed inside the inner frame while being supported by the inner frame.

[0035]

In the invention having the above constructions, the driving monitoring means for detecting the vibration in the driving direction of the vibrating body is provided in the barycentric region of the vibrating body. For example, when the vibrating body unnecessarily rotating-vibrates due to the adverse effect of an external force such as the acceleration, the center of the unwanted rotating vibration is located substantially in the barycentric region of the vibrating body and the vibration displacement in the driving direction due to the unwanted rotating vibration in the barycentric region of the vibrating body is small.

[0036]

Therefore, the driving monitoring means provided in the barycentric region of the vibrating body can substantially accurately detect the vibrating state of the vibrating body

in its driving direction while being hardly affected by the adverse effect of the unwanted rotating vibration. Because of this, even though the vibrating body unnecessarily rotating-vibrates, the vibrating body can stably vibrate by means of the positive feedback control based on the vibrating state in the driving direction of the vibrating body detected by the driving monitoring means.

[0037]

[Description of the Embodiments]

The embodiments according to the present invention are described below with reference to drawings.

[0038]

Fig. 1 shows one embodiment of a vibrator according to the present invention. This present embodiment is characterized in that driving monitoring means is provided in a barycentric region of a vibrating body. Otherwise, the construction of the vibrator is the same as that of a conventional example. In the description of this embodiment, construction components that are identical to the corresponding components in the conventional example have the same reference numerals, whereby the repeated descriptions of the identical components are omitted.

[0039]

In this embodiment, as shown in Fig. 1, comb-shaped detecting fixed electrode units 6 and detecting moveable

electrode units 15 are provided in an opposed manner inside an inner frame 14 so as to be engaged each other while maintaining a distance therebetween. Coriolis force direction vibration detecting means for causing these detecting fixed electrode units 6 and the detecting moveable electrode units 15 to detect the vibration of the vibrating body 8 in the Coriolis force direction (the Y direction in this embodiment) is constructed. Among these detecting fixed electrode units 6 and detecting moveable electrode units 15, the detecting fixed electrode units 6 and the detecting moveable electrode units 15 within a region surrounded by a dashed line M shown in Fig. 1 function as the driving monitoring means for detecting vibration displacement in a driving direction (X direction) of the vibrating body 8.

[0040]

As shown in Fig. 1, the driving monitoring means is provided in a barycentric region of the vibrating body 8 to detect the vibration displacement in the barycentric region of the vibrating body 8 in the driving direction.

[0041]

According to this embodiment, since the above driving monitoring means is provided in the barycentric region of the vibrating body 8, when the unwanted rotating vibration of the vibrating body 8 occurs due to the application of the

acceleration in the Y direction, the disturbance of the driving vibration of the vibrating body 8 caused by the unwanted rotating vibration can be avoided. That is, even though the vibrating body 8 unnecessarily rotating-vibrates due to above-described application of the acceleration, since the center of the unwanted rotating vibration is located in the barycentric region of the vibrating body 8, the vibration displacement in the barycentric region of the vibrating body 8 due to the above unwanted rotating vibration is reduced to small.

[0042]

Therefore, even though the vibrating body 8 unnecessarily rotating-vibrates by detecting the vibration displacement in the barycentric region of the vibrating body 8 using the driving monitoring means, the noise due to the above-described unwanted rotating vibration of the signal output from the above driving monitoring means becomes low.

[0043]

As a result of this, the normal positive feedback control is performed on the above vibrating body 8, which is hardly influenced by the occurrence of the above unwanted rotating vibration, so that the driving vibration stably continues. Because of this, the accurate angular velocity can be obtained regardless of the application of the acceleration.

[0044]

The inventors of the present invention confirmed this from an experiment. In this experiment, by preparing the vibrator provided with the driving monitoring means disposed in a region that is off the barycentric region of the vibrating body 8 as described in the conventional example and the vibrator provided with the driving monitoring means disposed in the barycentric region of the vibrating body 8 as shown in this embodiment, it was examined among these vibrators how different the levels of the signal components (noises) that are caused by the unwanted rotating vibration (acceleration application) contained in the output signals from the synchronous detecting unit 27 shown in Fig. 5. The results of the experiment are shown in Fig. 2.

[0045]

In the graphs in this Fig. 2, the horizontal axis indicates the frequency of the acceleration applied to the vibrating body 8, and the longitudinal axis indicates the level (acceleration sensitivity) of the above noise caused by the application of the acceleration. The solid line α indicates the experiment result obtained by using the conventional vibrator provided with the driving monitoring means disposed in the region that is off the barycentric region of the vibrating body 8, and the solid line β indicates the experimental result obtained by using the

vibrator according to the present embodiment provided with the driving monitoring means disposed in the barycentric region of the vibrating body 8.

[0046]

This Fig. 2 demonstrates that, by providing the driving monitoring means in the barycentric region of the vibrating body 8 as shown in this embodiment, the noise caused by the application of the acceleration can be considerably maintained at a low level compared to the conventional example.

[0047]

As is shown in the above experimental results, by providing the characteristic construction in this embodiment, the noise caused by the application of the acceleration contained in the output signal from the synchronous detecting unit 27 can be maintained at a low level. Consequently, the accurate angular velocity can be obtained.

[0048]

This invention is not restricted to the above embodiment and can take various forms of embodiments. For example, in the above embodiment, though the vibrating body 8 has a double-frame construction constructed by connecting the inner frame 14 to the inside of the outer frame 10 via the coupling beam (detecting beam) 13, the present invention can be applied to the vibrator provided with the vibrating

body having a construction other than the double-frame construction. For example, it can be applied to the vibrating body in the embodiment shown in Fig. 3.

[0049]

In Fig. 3, components whose names are the same as in the above embodiment have the same reference numerals as in the above embodiment. The vibrator 2 shown in this Fig. 3 constitutes the angular velocity sensor in the same manner as in the above embodiment. The vibrating body 8 of the vibrator 2 is supported at a support fixed unit 4 using a support beam 30 formed by being folded into an U-shape and can vibrate in two directions, the X direction and the Y direction shown in Fig. 3. By applying an alternating signal to the comb-shaped driving fixed electrode units 5 (5A, 5B), this vibrating body 8 driving-vibrates in the X direction in Fig. 3 due to change in the capacitance between the driving fixed electrode units 5 (5A, 5B) and the driving moveable electrode units 11 (11A, 11B).

[0050]

During such a driving-vibration, by rotating around the Z-axis, the vibrating body 8 vibrates in the Y direction in Fig. 3 due to the Coriolis force caused by the rotation. This vibration displacement is detected as the change in the capacitance between the detecting fixed electrode units 6 (6A, 6B, 6α, 6β) and the detecting moveable electrode units

15 (15A, 15B, 15α, 15β), so that the angular velocity of the rotation around the Z-axis can be detected. In the example shown in this Fig. 3, pairs of the detecting fixed electrode units 6α and 6β and the detecting moveable electrode units 15α and 15β function as the driving monitoring means. The positive feedback control is performed on the vibrating body 8 based on the vibrating state in the driving direction of the vibrating body 8 detected by this driving monitoring means.

[0051]

This driving monitoring means is provided in the barycentric region of the vibrating body 8 in the same manner as in the above embodiment. This can prevent the disturbance in the driving vibration of the vibrating body 8 due to the acceleration application in the same manner as in the above embodiment. Even though the vibrating body 8 unnecessarily rotating-vibrates due to the acceleration application, the angular velocity can be substantially accurately detected.

[0052]

In the above embodiments, although the description is made using the example of the vibrator embedded in the angular velocity sensor, this invention can be applied to the vibrator constituting a filter or the like.

[0053]

[Advantages]

According to this invention, since driving monitoring means is provided in the barycentric region of a vibrating body for detecting vibration displacement in a driving direction of the vibrating body, in other words, since, when the vibrating body unnecessarily rotating-vibrates, the above driving monitoring means is provided in the barycentric region of the vibrating body, which is the central part of the unwanted rotating vibration and which has a small vibration displacement, even though the above unwanted rotating vibration occurs, the noise caused by the above unwanted rotating vibration picked up in the signal output from the driving monitoring means can be maintained at a low level.

[0054]

This can prevent disturbance in the positive feedback control of the vibrating body due to the unwanted rotating vibration, so that the vibration in the driving direction of the vibrating body by driving means can be stably continued.

[0055]

When the vibrating body flexibly vibrating in the driving direction as well as in the Coriolis force direction is provided and the angular velocity is detected based on the vibration displacement in the Coriolis force direction of the vibrating body, since the vibration in the driving

direction of the vibrating body due to the unwanted rotating vibration can be prevented from being unstable in the above-described manner, the angular velocity can be substantially accurately detected regardless of occurrence of the unwanted rotating vibration.

[0056]

In the vibrating body having a double-frame construction, since the construction of the vibrating body is complicated, the unwanted rotating vibration tends to occur. Even though such unwanted rotating vibration occurs, since, as described above, the vibration in the driving direction of the vibrating body can be stably continued by reducing the adverse effect due to the unwanted rotating vibration to small, in a case in which the vibrating body has the double-frame construction, it is particularly effective that the driving monitoring means is provided in the barycentric region of the vibrating body.

[Brief Description of the Drawings]

[Fig. 1]

Fig. 1 is a model diagram illustrating one embodiment of a vibrator according to this present invention.

[Fig. 2]

Fig. 2 is a graph showing the effect of this embodiment using experimental results.

[Fig. 3]

Fig. 3 is a model diagram illustrating the other embodiment.

[Fig. 4]

Fig. 4 is a model diagram illustrating one example of a conventional vibrator.

[Fig. 5]

Fig. 5 is a block construction diagram schematically illustrating one example of a signal processing circuit for detecting the angular velocity by connecting to the vibrator.

[Fig. 6]

Fig. 6 consists of illustrations showing waveform examples of signals output from a C-V converting unit shown in Fig. 5.

[Fig. 7]

Fig. 7 is an illustration showing waveform examples of signals output from a differential amplifying unit shown in Fig. 5.

[Reference Numerals]

1: angular velocity sensor

2: vibrator

5: driving fixed electrode unit

6: detecting fixed electrode unit

8: vibrating body

9: driving beam

10: outer frame

11: driving moveable electrode unit

13: detecting beam

14: inner beam

15: detecting moveable electrode unit